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ABSTRACT

Many univariate statistical methods, such as the analysis of variance, t-test, and regression, assume that the dependent variable data have a univariate normal distribution (Hinkle, Weirsma, and Jurs, 1998). Various other statistical methods assume that the error scores are normally distributed (Thompson, 1992). Violating this assumption can be particularly problematic when examining statistical significance (R. Henson, 1999). Because countless people use the normal distribution in their daily lives to understand data ranging from advertisements to research articles, understanding the normal distribution is extremely important. A normal or nonnormal distribution cannot be determined simply by looking at the curve. To determine a distributions normality, one must analyze the data statistically. (Author/SLD)

There is More Than One Univariate Normal Distribution: What is the Normal Distribution, Really?

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Paper presented at the annual meeting of the Southwest Educational Research Association, Austin, TX, February 14-16, 2002.

Abstract

Many univariate statistical methods, such as the ANOVA, t-test, and regression, assume that the dependent variable data have a univariate normal distribution (cf. Hinkle, Weirsma, & Jurs, 1998, pp. 367-368). Various other statistical methods assume that the error scores are normally distributed (Thompson, 1992). Violating this assumption can be particularly problematic when examining statistical significance (Henson, 1999). Because countless people use the normal distribution in their daily lives to understand data ranging from advertisements to research articles, understanding the normal distribution is extremely important.

Many univariate statistical methods, such as the ANOVA, t-test, and regression, assume that the dependent variable data have a univariate normal distribution (cf. Hinkle, Weirsma, & Jurs, 1998, pp. 367-368). Various other statistical methods assume that the error scores are normally distributed (Thompson, 1992). Violating this assumption can be particularly problematic when examining statistical significance (Henson, 1999). Because countless people use the normal distribution in their daily lives to understand data ranging from advertisements to research articles, understanding the normal distribution is extremely important.

The normal curve has many useful mathematical properties (Bump, 1991). One example includes the use of the normal curve to determine the percentage of people scoring within selected SD units from the mean (Bump, 1991). In the normal distribution, 68% of the scores fall between the mean and plus or minus one SD, 95% fall within plus or minus two SD from the mean, and 99% fall within plus or minus three SD from the mean. For these various reasons, Wilcox (1996, p.63) stated that the normal distribution is "the most important distribution in all of statistics."

People often believe the fallacy that the normal curve can only be the classical "bell" shaped curve seen in textbooks. This most commonly pictured normal curve is actually the standard normal curve (i.e. z scores that are normally distributed) (Hinkle et al., 1998). In reality, the normal curve has infinitely many possible curve shapes and sizes. The misconception that the standard normal curve is the single possible normal curve undermines the normal curve's true properties. The data used in a normal curve must be intervally scaled. Most intervally scale variables yield normal or quasi-normal distributions when data are collected from large samples, and the normal Z distribution is also used as a test statistic in some statistical significance testing (Bump, 1991). Using the "look" of a distribution to determine normality is inadequate.

The necessary properties of the normal distribution curve include:

1. The curve is symmetrical. The mean, median, and mode coincide.
2. Maximum height is at the mean/median/mode.
3. The normal distribution is continous. There is an Y value for every X value.

4. The curve is asymptotic. It approaches the X-axis, but it does not meet the X-axis and extends from negative infinity to positive infinity.

Needless to say, these properties of the normal curve do not limit the shape of the curve solely to the classic "bell" shape that is most often identified as the "normal curve." For every possible mean and standard deviation, there is a unique normal distribution that makes up a family of distributions (Hinkle et al., 1998, p. 91).

That is, a normal distribution with a near-zero SD will look tall and narrow. A normal distribution with a large SD will look flat and wide. But both such distributions are perfectly normal distributions. And because there are infinitely many values for SD (and the mean as well), there are infinitely many normal distributions.

In order to have a normal distribution, the distribution's measures of central tendency (average scores) must lie near the center of the distribution (Hinkle et al., 1998, p. 61). Therefore, the mean, median, and mode are identical. The normal curve can take infinitely many forms, each having skewness and kurtosis coefficients of zero (Bump, 1991; Burdenski, 2000; Henson, 1999), but differing in appearance (e.g., apparent width and apparent height).

Skewness and kurtosis have an effect on the ability of a distribution to be defined as normal or not. In univariate cases, normality is assessed by the value of a kurtosis coefficient (Henson, 1999). Kurtosis indicates the shape of a distribution relative to the normal distribution, by comparing the relative height to width of a distribution curve (Henson, 1999). Kurtosis is the forth moment about the mean, it accompanied with three other moments about the mean help identify a distribution as normal. The first moment is the mean itself, the second is the standard deviation, and the third is the coefficient of skewness. The kurtosis coefficient is computed by the formula:

$$K_x = \{[(n(n+1)) / ((n-1)(n-2)(n-3))] [\Sigma(((X_i - \bar{X}) / SD_x)^4)]\} - [(3 ((n-1)^2)) / ((n-2)(n-3))] \text{ or}$$
$$\{[(n (n+1)) / ((n-1)(n-2)(n-3))] (\Sigma (Z_i^4))\} - [(3 ((n-1)^2)) / ((n-2) (n-3))]$$

Researchers typically apply the additive constant, -3 to the result so that the result will be zero for a distribution that is univariate normal (Henson, 1999). Therefore, the kurtosis coefficient of zero indicates that the shape directly corresponds to the shape of the univariate normal distribution. Henson (1999) further explained that there must be an appropriate proportion of distribution height to width for normality to exist.

Skewness is the degree of symmetry or non-symmetry in a distribution. The formula:

$$S_x = [n \,/\, ((n-1)(n-2))]\ [\Sigma(((x_i - \bar{x})\ /\ SD_x)^3)] \text{ or }$$
$$[n \,/\, ((n-1)(n-2))]\ (\Sigma\ (Z_i^3))$$

is used to assess skewness. In a skewed distribution, the majority of the scores are located at one end of the measurement with progressively fewer towards the other end (Hinkle et al., 1998, p. 621). Symmetry is necessary in order to have a normal distribution, however a symmetrical distribution may not be a normal distribution. For example, a bimodal distribution is often symmetrical but does not represent a normal distribution. Symmetrical distributions have a skewness coefficient of zero, therefore positive values indicate positively skewed or skewed to the right or negatively skewed or skewed to the left (Henson, 1999; Hinkle et al., 1998, p. 42).

Heuristic Examples

Table 1 presents a heuristic data set of 100 cases of data for the variable "x". These data are very close to normally distributed, as portrayed in the descriptive statistics in Table 2.

INSERT TABLES 1 AND 2 ABOUT HERE

Using the SPSS syntax located in the Appendix, 4 variables were computed (i.e., "mean0_1", "mean0_2", "mean0_3", and "mean0_4"), all with equal means. As seen in Table 2, the standard deviations of each set of variables differ.

Each set of variables exemplifies the normal curve even though they differ in "spreadoutness". The normality of these curves is confirmed by the coefficients of skewness and kurtosis in Table 2. Both coefficients equal approximately zero. Also, in Figures 1 through 4 the normality of the data set is graphically compared to the normal curve. The data distributions of the normal curve are placed over the actual data distributions.

INSERT FIGURES 1 THROUGH 4 ABOUT HERE

Using the SPSS syntax located in the Appendix, 3 variables were computed (i.e. "mean_1", "mean_2", and "mean_3"). As seen in Table 2 neither the means nor the standard deviations were equal.

Although, these 3 distributions differ in their "spreadoutness", the variables are approximately normal.

This can be confirmed in Table 2, as the skewness and kurtosis coefficients equal nearly zero. It can also be confirmed in Figures 5 through 7 where the graphs of the data is seen with the normal curve imposed over the actual data distributions.

INSERT FIGURES 5 THROUGH 7 ABOUT HERE

As mentioned previously, "eyeballing" a curve is insufficient in determining whether or not a distribution is normal. Therefore, nongraphical tests may also be utilized to determine the normality of a distribution. These nongraphical tests include the chi-square goodness of fit, Kolmogorov-Smirnov, the Shaprio-Wilk test, as well as the use of skewness and kurtosis coefficients (Stevens, 2002, p. 264). According to Stevens (2002), investigators have studied the usefulness of these tests and determined that the combination of skewness and kurtosis coefficients and the Shaprio-Wilk test were the most powerful in determining normality. They also found that extreme nonnormality could be detected with sample sizes less than 20 by using sensitive procedures (like the two just mentioned). This proves important, because for many practical problems, the group sizes are small (Stevens, 2002, p. 264).

As seen, graphical techniques can be helpful in assessing univariate normality. Several of the graphical methods for testing normality exist. One particular test is the normal probability plot or Q-Q Plot (quantile-versus-quantile) in which the observations are ordered in increasing degree of magnitude and then plotted against expected normal distribution values (Burdenski, 2000). The closer the line is to a straight line, the more correlated the observed score is with the expected score and the more normal the distribution (Burdenski, 2000). Three other graphical tests include the box-and whisker- plot, stem-and-leaf plot, and a histogram of the dependent variables. Burdenski (2000) stated that these tests allow a quick and simple means of evaluating the shape of the univariate distribution for each dependent variable. The graphical and nongraphical testing techniques allow the researcher to fully determine the normality of a univariate distribution. Because the fallacy of using only the look of a curve to determine its normality has been proven to be inadequate, these other assessment techniques prove to be helpful.

Summary

The univariate normal distribution has infinitely many shapes. Through the graphs, several examples have been given showing one way data can be manipulated and the normal distributions still exist. Each graph portrays a slightly different look of the normal distribution, while each data set maintained skewness and kurtosis values that were exactly the same.

A normal or nonnormal distribution cannot be determined by simply looking at the curve. To determine a distribution's normality, one must analyze the data statistically. Because many people confuse the typical "bell" shape curve as the one and only normal distribution, it is important to understand that bells can come in many different shapes as can the normal curve.

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Table 1
Heuristic Data (n=100)
From Thompson (2002)

ID	x
1	24.00
2	28.00
3	30.00
4	32.00
5	33.00
6	34.00
7	35.00
8	36.00
9	36.00
10	37.00
11	37.00
12	38.00
13	38.00
14	39.00
15	39.00
16	40.00
17	40.00
18	41.00
19	41.00
20	41.00
21	42.00
22	42.00
23	42.00
24	43.00
25	43.00
26	43.00
27	44.00
28	44.00
29	44.00
30	45.00
31	45.00
32	45.00
33	46.00
34	46.00
35	46.00
36	46.00
37	47.00
38	47.00
39	47.00
40	47.00
41	48.00
42	48.00
43	48.00
44	48.00
45	49.00
46	49.00
47	49.00
48	49.00
49	50.00
50	50.00
51	50.00
52	50.00

53	51.00
54	51.00
55	51.00
56	51.00
57	52.00
58	52.00
59	52.00
60	52.00
61	53.00
62	53.00
63	53.00
64	53.00
65	54.00
66	54.00
67	54.00
68	54.00
69	55.00
70	55.00
71	55.00
72	56.00
73	56.00
74	56.00
75	57.00
76	57.00
77	57.00
78	58.00
79	58.00
80	58.00
81	59.00
82	59.00
83	59.00
84	60.00
85	60.00
86	61.00
87	61.00
88	62.00
89	62.00
90	63.00
91	63.00
92	64.00
93	64.00
94	65.00
95	66.00
96	67.00
97	68.00
98	70.00
99	72.00
100	76.00

Table 2
Descriptive Statistics

	Statistics			
Variable	Mean	SD	Coef. Of Skewnes	Coef. of Kurtosis
x	50.00	10.05	.000	-.090
mean0_1	0.00	10.05	.000	-.090
mean0_2	0.00	5.02	.000	-.090
mean0_3	0.00	15.07	.000	-.090
mean0_4	0.00	40.20	.000	-.090
mean_1	25.00	5.02	.000	-.090
mean_2	75.00	15.07	.000	-.090
mean_3	200.00	40.20	.000	-.090

a"mean0_1" = "x" - 50.
b= "mean0_1" * .5
c= "mean0_1" * 1.5
d= "mean0_1" * 4.

e= "x" * .5
f= "x" * 1.5
g= "x" * 4.

Table 3
Scores n=100 for Three Variances
Each with Means = .000

ID	MEAN0_1	MEAN0_2	MEAN0_3	MEAN0_4
1	-26.00000	-13.00000	-39.00000	-104.0000
2	-22.00000	-11.00000	-33.00000	-88.00000
3	-20.00000	-10.00000	-30.00000	-80.00000
4	-18.00000	-9.000000	-27.00000	-72.00000
5	-17.00000	-8.500000	-25.50000	-68.00000
6	-16.00000	-8.000000	-24.00000	-64.00000
7	-15.00000	-7.500000	-22.50000	-60.00000
8	-14.00000	-7.000000	-21.00000	-56.00000
9	-14.00000	-7.000000	-21.00000	-56.00000
10	-13.00000	-6.500000	-19.50000	-52.00000
11	-13.00000	-6.500000	-19.50000	-52.00000
12	-12.00000	-6.000000	-18.00000	-48.00000
13	-12.00000	-6.000000	-18.00000	-48.00000
14	-11.00000	-5.500000	-16.50000	-44.00000
15	-11.00000	-5.500000	-16.50000	-44.00000
16	-10.00000	-5.000000	-15.00000	-40.00000
17	-10.00000	-5.000000	-15.00000	-40.00000
18	-9.000000	-4.500000	-13.50000	-36.00000
19	-9.000000	-4.500000	-13.50000	-36.00000
20	-9.000000	-4.500000	-13.50000	-36.00000
21	-8.000000	-4.000000	-12.00000	-32.00000
22	-8.000000	-4.000000	-12.00000	-32.00000
23	-8.000000	-4.000000	-12.00000	-32.00000
24	-7.000000	-3.500000	-10.50000	-28.00000
25	-7.000000	-3.500000	-10.50000	-28.00000
26	-7.000000	-3.500000	-10.50000	-28.00000
27	-6.000000	-3.000000	-9.000000	-24.00000
28	-6.000000	-3.000000	-9.000000	-24.00000
29	-6.000000	-3.000000	-9.000000	-24.00000
30	-5.000000	-2.500000	-7.500000	-20.00000
31	-5.000000	-2.500000	-7.500000	-20.00000
32	-5.000000	-2.500000	-7.500000	-20.00000
33	-4.000000	-2.000000	-6.000000	-16.00000
34	-4.000000	-2.000000	-6.000000	-16.00000
35	-4.000000	-2.000000	-6.000000	-16.00000
36	-4.000000	-2.000000	-6.000000	-16.00000
37	-3.000000	-1.500000	-4.500000	-12.00000
38	-3.000000	-1.500000	-4.500000	-12.00000
39	-3.000000	-1.500000	-4.500000	-12.00000
40	-3.000000	-1.500000	-4.500000	-12.00000
41	-2.000000	-1.000000	-3.000000	-8.000000
42	-2.000000	-1.000000	-3.000000	-8.000000
43	-2.000000	-1.000000	-3.000000	-8.000000
44	-2.000000	-1.000000	-3.000000	-8.000000
45	-1.000000	-.5000000	-1.500000	-4.000000
46	-1.000000	-.5000000	-1.500000	-4.000000
47	-1.000000	-.5000000	-1.500000	-4.000000
48	-1.000000	-.5000000	-1.500000	-4.000000
49	.0000000	.0000000	.0000000	.0000000
50	.0000000	.0000000	.0000000	.0000000

51	.0000000	.0000000	.0000000	.0000000
52	.0000000	.0000000	.0000000	.0000000
53	1.0000000	.5000000	1.5000000	4.0000000
54	1.0000000	.5000000	1.5000000	4.0000000
55	1.0000000	.5000000	1.5000000	4.0000000
56	1.0000000	.5000000	1.5000000	4.0000000
57	2.0000000	1.0000000	3.0000000	8.0000000
58	2.0000000	1.0000000	3.0000000	8.0000000
59	2.0000000	1.0000000	3.0000000	8.0000000
60	2.0000000	1.0000000	3.0000000	8.0000000
61	3.0000000	1.5000000	4.5000000	12.000000
62	3.0000000	1.5000000	4.5000000	12.000000
63	3.0000000	1.5000000	4.5000000	12.000000
64	3.0000000	1.5000000	4.5000000	12.000000
65	4.0000000	2.0000000	6.0000000	16.000000
66	4.0000000	2.0000000	6.0000000	16.000000
67	4.0000000	2.0000000	6.0000000	16.000000
68	4.0000000	2.0000000	6.0000000	16.000000
69	5.0000000	2.5000000	7.5000000	20.000000
70	5.0000000	2.5000000	7.5000000	20.000000
71	5.0000000	2.5000000	7.5000000	20.000000
72	6.0000000	3.0000000	9.0000000	24.000000
73	6.0000000	3.0000000	9.0000000	24.000000
74	6.0000000	3.0000000	9.0000000	24.000000
75	7.0000000	3.5000000	10.500000	28.000000
76	7.0000000	3.5000000	10.500000	28.000000
77	7.0000000	3.5000000	10.500000	28.000000
78	8.0000000	4.0000000	12.000000	32.000000
79	8.0000000	4.0000000	12.000000	32.000000
80	8.0000000	4.0000000	12.000000	32.000000
81	9.0000000	4.5000000	13.500000	36.000000
82	9.0000000	4.5000000	13.500000	36.000000
83	9.0000000	4.5000000	13.500000	36.000000
84	10.000000	5.0000000	15.000000	40.000000
85	10.000000	5.0000000	15.000000	40.000000
86	11.000000	5.5000000	16.500000	44.000000
87	11.000000	5.5000000	16.500000	44.000000
88	12.000000	6.0000000	18.000000	48.000000
89	12.000000	6.0000000	18.000000	48.000000
90	13.000000	6.5000000	19.500000	52.000000
91	13.000000	6.5000000	19.500000	52.000000
92	14.000000	7.0000000	21.000000	56.000000
93	14.000000	7.0000000	21.000000	56.000000
94	15.000000	7.5000000	22.500000	60.000000
95	16.000000	8.0000000	24.000000	64.000000
96	17.000000	8.5000000	25.500000	68.000000
97	18.000000	9.0000000	27.000000	72.000000
98	20.000000	10.000000	30.000000	80.000000
99	22.000000	11.000000	33.000000	88.000000
100	26.000000	13.000000	39.000000	104.00000

Table 4
Scores (n = 100) for Three Variances
Each with Means ≠ .000

ID	MEAN_1	MEAN_2	MEAN_3
1	12.000000	36.000000	96.000000
2	14.000000	42.000000	112.00000
3	15.000000	45.000000	120.00000
4	16.000000	48.000000	128.00000
5	16.500000	49.500000	132.00000
6	17.000000	51.000000	136.00000
7	17.500000	52.500000	140.00000
8	18.000000	54.000000	144.00000
9	18.000000	54.000000	144.00000
10	18.500000	55.500000	148.00000
11	18.500000	55.500000	148.00000
12	19.000000	57.000000	152.00000
13	19.000000	57.000000	152.00000
14	19.500000	58.500000	156.00000
15	19.500000	58.500000	156.00000
16	20.000000	60.000000	160.00000
17	20.000000	60.000000	160.00000
18	20.500000	61.500000	164.00000
19	20.500000	61.500000	164.00000
20	20.500000	61.500000	164.00000
21	21.000000	63.000000	168.00000
22	21.000000	63.000000	168.00000
23	21.000000	63.000000	168.00000
24	21.500000	64.500000	172.00000
25	21.500000	64.500000	172.00000
26	21.500000	64.500000	172.00000
27	22.000000	66.000000	176.00000
28	22.000000	66.000000	176.00000
29	22.000000	66.000000	176.00000
30	22.500000	67.500000	180.00000
31	22.500000	67.500000	180.00000
32	22.500000	67.500000	180.00000
33	23.000000	69.000000	184.00000
34	23.000000	69.000000	184.00000
35	23.000000	69.000000	184.00000
36	23.000000	69.000000	184.00000
37	23.500000	70.500000	188.00000
38	23.500000	70.500000	188.00000
39	23.500000	70.500000	188.00000
40	23.500000	70.500000	188.00000
41	24.000000	72.000000	192.00000
42	24.000000	72.000000	192.00000
43	24.000000	72.000000	192.00000
44	24.000000	72.000000	192.00000
45	24.500000	73.500000	196.00000
46	24.500000	73.500000	196.00000
47	24.500000	73.500000	196.00000
48	24.500000	73.500000	196.00000
49	25.000000	75.000000	200.00000
50	25.000000	75.000000	200.00000

51	25.000000	75.000000	200.00000
52	25.000000	75.000000	200.00000
53	25.500000	76.500000	204.00000
54	25.500000	76.500000	204.00000
55	25.500000	76.500000	204.00000
56	25.500000	76.500000	204.00000
57	26.000000	78.000000	208.00000
58	26.000000	78.000000	208.00000
59	26.000000	78.000000	208.00000
60	26.000000	78.000000	208.00000
61	26.500000	79.500000	212.00000
62	26.500000	79.500000	212.00000
63	26.500000	79.500000	212.00000
64	26.500000	79.500000	212.00000
65	27.000000	81.000000	216.00000
66	27.000000	81.000000	216.00000
67	27.000000	81.000000	216.00000
68	27.000000	81.000000	216.00000
69	27.500000	82.500000	220.00000
70	27.500000	82.500000	220.00000
71	27.500000	82.500000	220.00000
72	28.000000	84.000000	224.00000
73	28.000000	84.000000	224.00000
74	28.000000	84.000000	224.00000
75	28.500000	85.500000	228.00000
76	28.500000	85.500000	228.00000
77	28.500000	85.500000	228.00000
78	29.000000	87.000000	232.00000
79	29.000000	87.000000	232.00000
80	29.000000	87.000000	232.00000
81	29.500000	88.500000	236.00000
82	29.500000	88.500000	236.00000
83	29.500000	88.500000	236.00000
84	30.000000	90.000000	240.00000
85	30.000000	90.000000	240.00000
86	30.500000	91.500000	244.00000
87	30.500000	91.500000	244.00000
88	31.000000	93.000000	248.00000
89	31.000000	93.000000	248.00000
90	31.500000	94.500000	252.00000
91	31.500000	94.500000	252.00000
92	32.000000	96.000000	256.00000
93	32.000000	96.000000	256.00000
94	32.500000	97.500000	260.00000
95	33.000000	99.000000	264.00000
96	33.500000	100.50000	268.00000
97	34.000000	102.00000	272.00000
98	35.000000	105.00000	280.00000
99	36.000000	108.00000	288.00000
100	38.000000	114.00000	304.00000

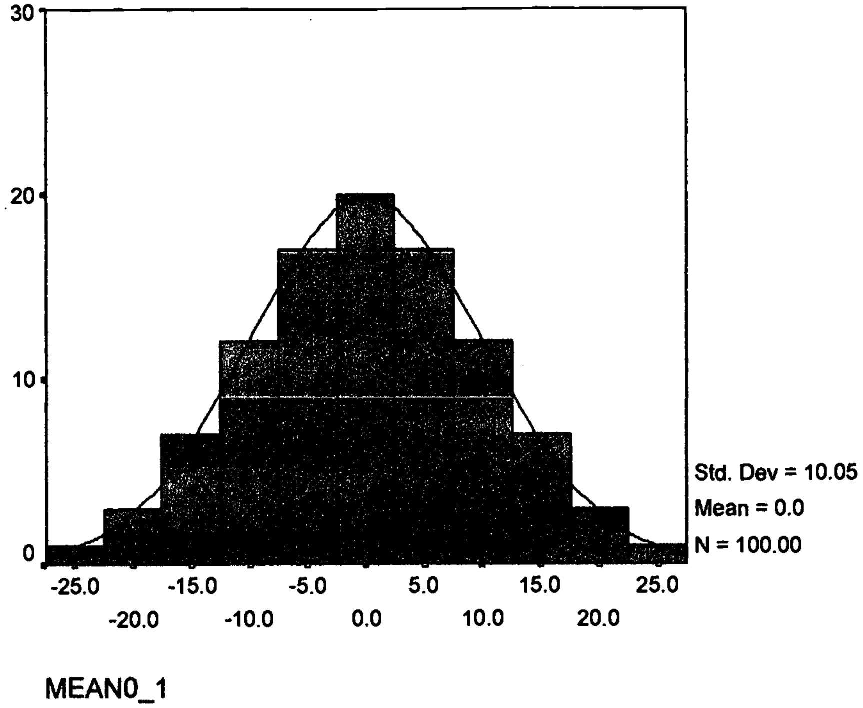


Figure 1

Figure 2

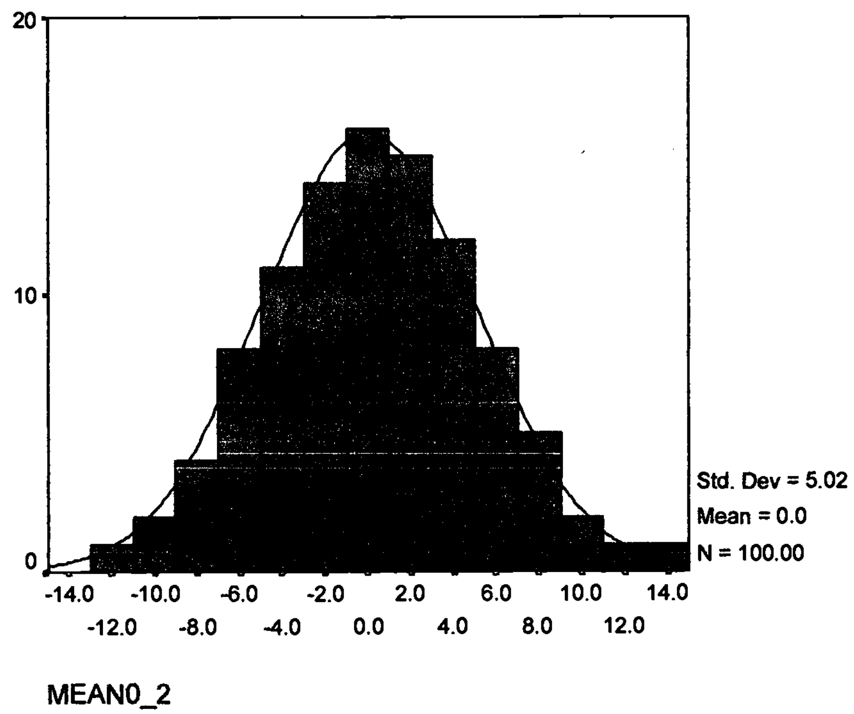


Figure 3

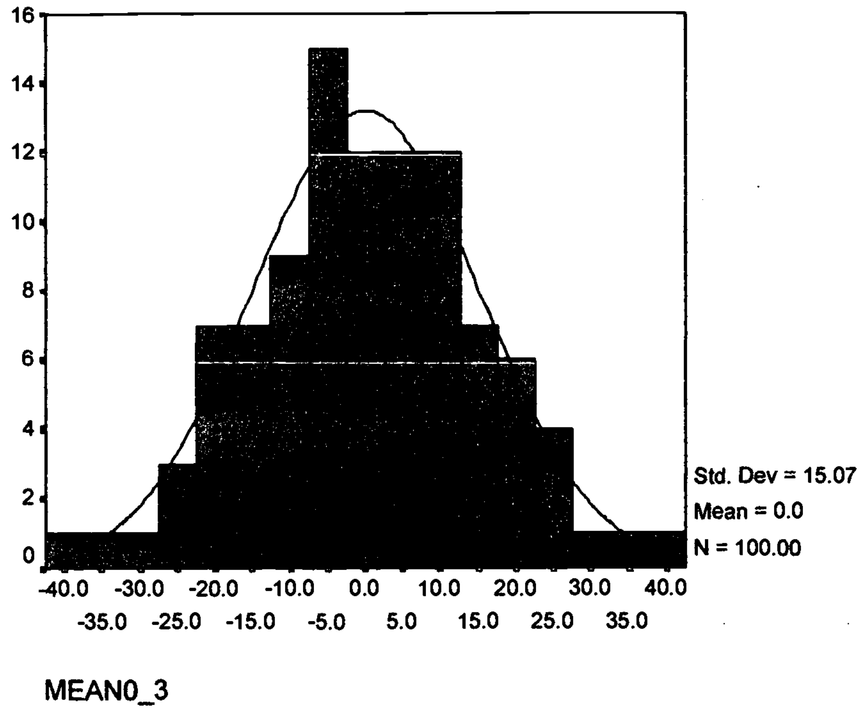

16
14
12
10
8
6
4
2
0
-40.0
-30.0
-20.0
-10.0
0.0
10.0
20.0
30.0
40.0
-35.0
-25.0
-15.0
-5.0
5.0
15.0
25.0
35.0
Std. Dev = 15.07
Mean = 0.0
N = 100.00
MEAN0_3

Figure 4

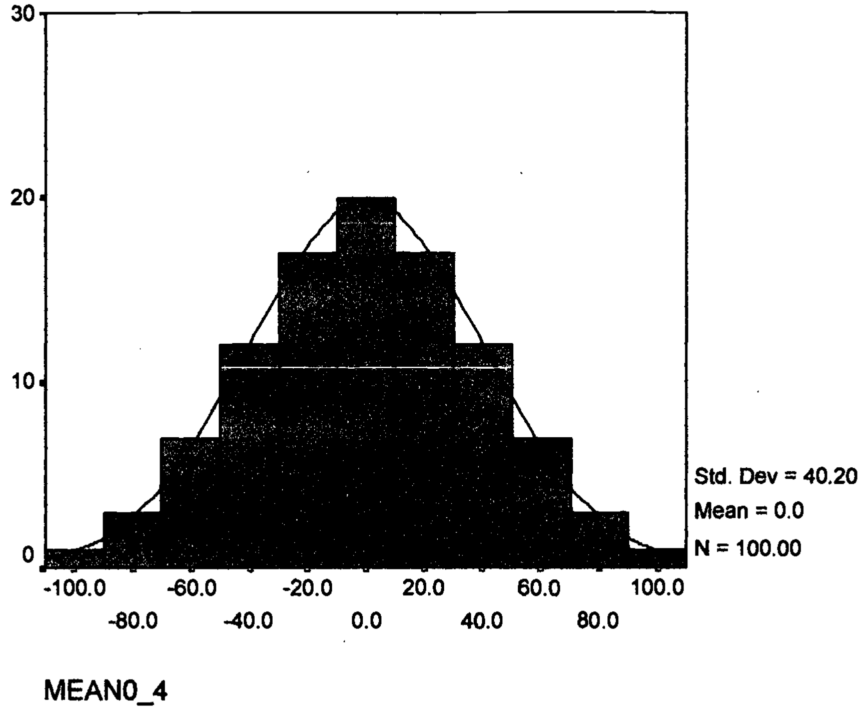


Figure 5

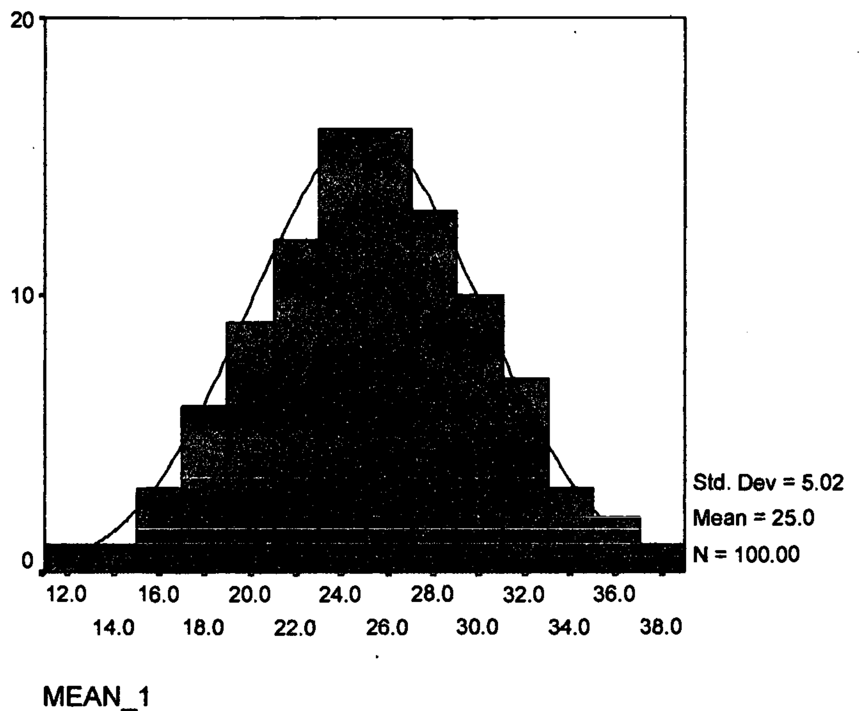


Figure 6

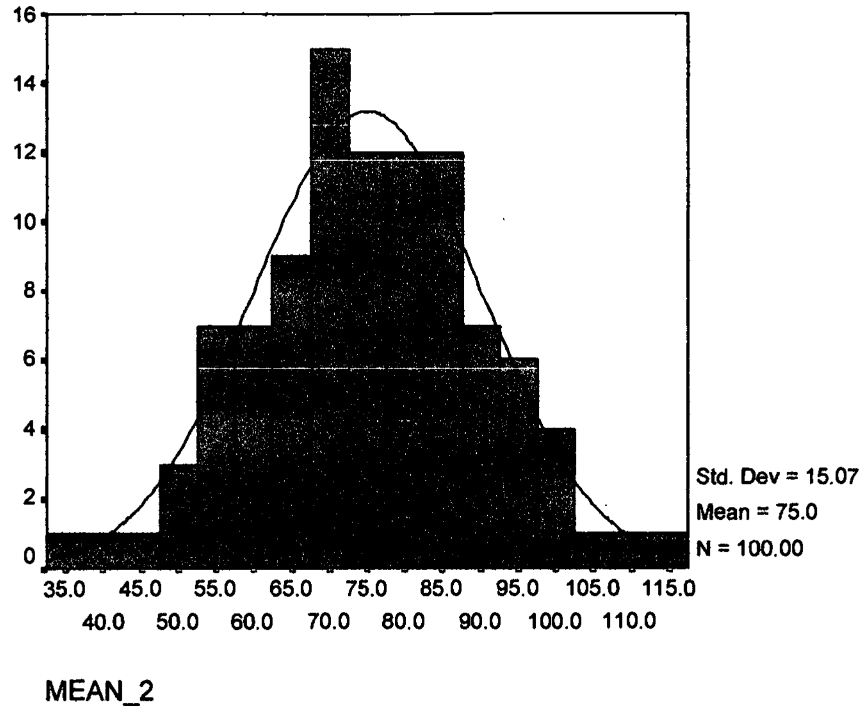
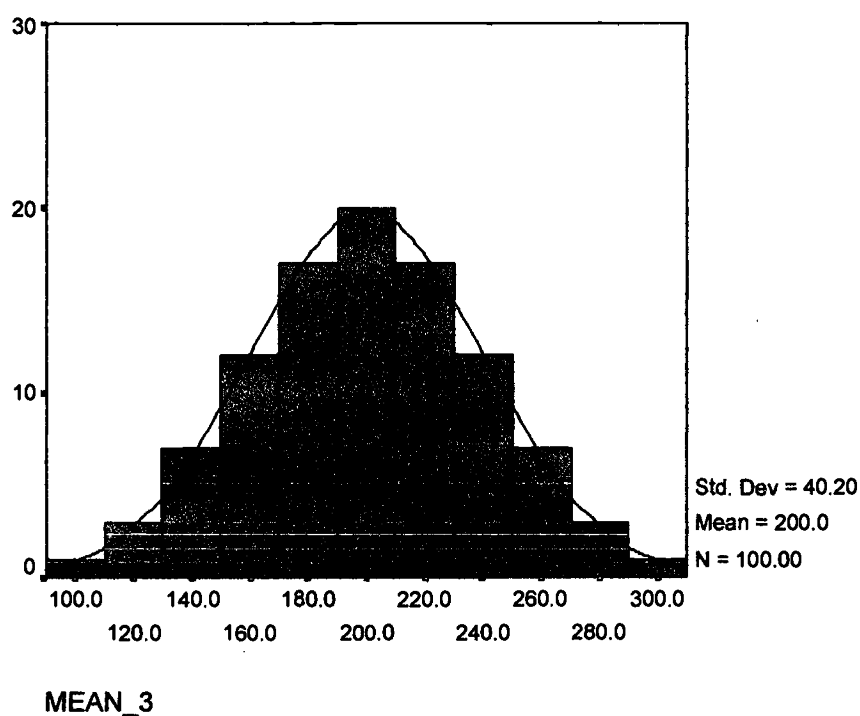


Figure 7



```
SET BLANKS=SYSMIS UNDEFINED=WARN printback=listing .
TITLE 'Bruce Thompson's normal data *************' .
DATA LIST
FILE= 'a:\normal2.txt' FIXED RECORDS=1 TABLE/1 id 1-3 x 4-
12 .
List variables=all/cases=999 .

subtitle '1 show several normal with same Mean ***' .
execute .
compute mean0_1 = x - 50. .
compute mean0_2 = mean0_1 * .5 .
compute mean0_3 = mean0_1 * 1.5 .
compute mean0_4 = mean0_1 * 4. .
list variables=id mean0_1 to mean0_4/cases=999 .
descriptives variables=x mean0_1 to mean0_4/statistics=all
.

subtitle '2 show several normal with *dif* Mean ***' .
execute.
compute mean_1 = x * .5 .
compute mean_2 = x * 1.5 .
compute mean_3 = x * 4. .
list variables=id mean_1 to mean_3/cases=999 .
descriptives variables=x mean_1 to mean_3/statistics=all .
GRAPH
  /HISTOGRAM(NORMAL) =mean0_1 .
GRAPH
  /HISTOGRAM(NORMAL)=mean0_2 .
GRAPH
  /HISTOGRAM(NORMAL)=mean0_3 .
GRAPH
  /HISTOGRAM(NORMAL)=mean0_4 .
GRAPH
  /HISTOGRAM(NORMAL)=mean_1 .
GRAPH
  /HISTOGRAM(NORMAL)=mean_2 .
GRAPH
  /HISTOGRAM(NORMAL)=mean_3 .
```

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